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Biomechanical Analysis of the User's Movements during Tactile Interaction: Postures of Older Aged Users' Wrists

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ABSTRACT
With the emergence of devices equipped with touchscreen, it is necessary to understand the difficulties older aged adults find for executing the gestures of tactile interaction in order to prevent the digital exclusion of this group of users. The association of the analysis of the users' movements to the study of their interaction with touchscreen provide additional information for the interpretation of the results. In the present study, we recorded the movements of older and younger adults during interaction with a tablet, horizontally placed on a desk. We identified differences in the characteristics of the postures of the users' wrists, particularly a greater angular amplitude for older participants which could explain the longer times and the increased number of errors for this group of users. In this paper, we discuss the usability of tactile interaction from an ergonomic perspective.

Author Keywords
Movement analysis; touchscreen; tactile interaction; older aged adults; wrist articulation.

INTRODUCTION
With the emergence of devices equipped with touchscreen, it is necessary to understand the difficulties users may find for executing the interaction gestures. A new approach for studying the differences in performances between users is the association of the biomechanical analysis of their movements to the analysis of the information of the interaction registered by the interactive system. The analysis of the postures and positions of the users' bodies reveals the strategies the users adopt to execute the gestures of interaction in order to accomplish interaction tasks on touchscreen [6,11,18]. Therefore, previous studies have shown how the characteristics of the movements of the users can have consequences on their interaction performances, according to the different situations of use of touchscreen devices [1,8].

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We surveyed research studies about the users' movements during interaction with touchscreen and we found that a joint assessment of performances and movements of older aged users remained to be done. We believe this analysis should provide information for helping to understand the different performances between older and younger users. For the aging societies, improving the ergonomics of touchscreen devices is particularly important to prevent older aged adults to be digitally excluded.

Therefore, we have implemented a study associating the analysis of the movements to the analysis of the interaction data registered by the interactive system on touchscreen. Our main goal is to understand the differences in performances between older and younger adults during interaction. The main contribution of our study is to have identified differences in the characteristics of movements of the users' wrists between these two groups of participants. The results we obtained open up new perspectives for the evaluation of the ergonomics of interaction with technologies.

The remaining of this paper is organized as follows. First, the analysis of the state of the art aims to define the specifications for the experimental protocol. Then, we describe the experiment, the data analysis and the results we obtained. Finally, we discuss the usability of tactile interaction from an ergonomic point of view and the challenges of the implementation of this multidisciplinary experiment.

STATE OF THE ART
We surveyed research studies on movement analysis of tactile interaction. We have selected thirteen studies evaluating postures and movements of human adult users during interaction with touchscreen devices [1,4–9,11,13–15,18,19]. These studies have been published between 2011 and 2017 in journals and conferences from different research fields, including Ergonomics, Modelling of Human Movement, Accessibility and Human Computer-Interaction (HCI).

Older aged adults are a heterogeneous group of users. The changes related to the aging in cognitive, motor and sensorial skills are individual [2]. Besides, other factors such as educational level, professional activity and previous experience with computers or mobile phones can influence user's attitudes towards new technologies [10]. HCI studies have been providing information and guidelines to help designers to address the diversity of older users' skills and special needs. However, recruiting older aged participants can present some barriers such as the mobility until the laboratory, the length of the experiment and the accessibility of the task [2]. In our study, we try to facilitate the participation of older aged adults.

The aim of the present state of the art was to define the equipment and the configuration of the experiment for studying the movements of older aged users during a task of interaction with touchscreen.

Therefore, we are interested in the different criteria applied for the implementation of the experiments in the studies we reviewed, particularly in regard to:

- The characteristics of the participants;
- The equipment used for recording movement data;
- The configuration of the experiment and touchscreen devices.

Characteristics of the participants

From the studies we reviewed, ten studies included adult participants who did not present any motor disability nor musculoskeletal disorder that could hinder interaction with touchscreens. The three other studies evaluated movements of participants with special needs or illnesses affecting the control of upper limb (ex. Cerebral Palsy, Multiple Sclerosis, Parkinson disease) [4,5,13]. These three studies described the effects of a low motor control on the user's movements during interaction and their consequences in users' performances. No study evaluating movements of older aged adults during tactile interaction have been found.

When considering the studies on biomechanics research field, the homogeneity of the characteristics of the participants aims to facilitate the definition of the biomechanical indexes (e.g. articular angles of the wrist) and their evaluation. In the studies we reviewed, authors have measured and reported heights and weights of the participants [14] or the size of their hands [18,19]. In one study, the size of the participants' hands was an inclusion criteria [11]. Indeed, different morphologies can have an effect on users performances and comfort of use [12]. Besides, gathering a homogeneous group of participants allowed authors to evaluate articular angles of user's bodies using the same study configuration for all the participants.

For studies on HCI, on the other hand, the homogeneity of the user profiles (i.e. age ranges, motor difficulties, novice or experienced users) aims to identify specific needs of particular users groups. Among the studies we reviewed in this state of the art, previous experience with technologies was an inclusion criterion. For example, four studies have recruited only participants experts on text typing tasks [8,9,14,15]. Three studies have verified participants' previous experience of use of touchscreen : two of them have recruited only participants who were familiar to these devices [18,19] and the other study has included only novice users [11]. Concerning the specificities of older aged adults as a user group, to respond to the diversity of their needs and expectations, assessing their user profiles can be used to explain the variability of performances between participants.

Equipment for recording movement data

Table 1 presents the equipment that have been used for recording movements of the users, as well as the parts of the bodies involved during the execution of the gestures of interaction with touchscreen.

Kind of equipment	Measures and settings
Motion capture	Postures of hands, wrists, forearms, arms, trunk and head [6,7,18,19] or full body [1]
Electromyography (EMG)	Muscle activity of users' fingers, hands, forearms, arms and neck [8,9,11,14,15,18]
Electrogoniometer	Articular angles of wrists and shoulders [15,18]
Force plate	Force, orientation and pressure of the gesture [4,5,13]

Table 1. Equipment for recording users' movement

The equipment used for motion capture are usually cumbersome and require a controlled environment, such as a university laboratory. Otherwise, signals can be troubled with noise or interferences. On the other hand, small markers and sensors are attached to the users' skin or skin-tight garments for tracking and recording movements of the participants. This equipment is non-invasive and allows a great freedom of movements for the participants. Motion capture systems allow to register not only the postures of the users but also their positions and mobility around the tactile devices [1].

To measure discomfort and to identify risks for developing musculoskeletal injuries, researchers have used equipment for recording muscle activity (electromyography) or articulatory angles (goniometer). Even if this equipment is also non-invasive, the devices attached to the user's articulations are voluminous and could hinder the movements of the user during an interaction task.

Force plates are connected to the devices and usually do not interfere on the user's movements. Force plates can be used to estimate the force and the orientation of a movement from the pressure exerted on the device. This equipment does not give information about the postures and the positions of the users.

Configuration of the studies and touchscreen devices

Touchscreen devices are available on different sizes and can be used in different settings. Table 2 describes the screen sizes and the configuration of their use in the studies we reviewed. Some studies compared the movements of the users during interaction with different screen sizes and orientations [1,6,7,11,18,19]. Other studies compared touchscreen to other devices, such as physical keyboards and notebooks [5,8].

Screen sizes	Configuration of the studies
Big (15 inches or bigger) (e.g. tabletop)	• Fixed, vertical position* (kiosk style) [1,4,5,13,14] • Fixed, horizontal position [8,9]
Middle (6 to 12 inches) (e.g. tablet)	• Fixed, vertical position * (with case) [18,19] • Fixed, horizontal position [6,7,9,15,19] • Handheld [1,11]
Small (3 to 6 inches) (e.g. smartphone)	• Fixed, horizontal position [6,7] • Handheld [1,11]

Table 2. Screen sizes and configuration of the studies

* Inclination angle 60° or higher

Among the selected studies, six of them recorded interaction data on the screen to evaluate the users' performances [1,4,6,8,13,15]. The other studies reported only movement data. Indeed, all the studies have shown that users adapt their movements according to the configuration of use of touchscreen.

Four studies evaluated the effects of the configuration of use not only on the users' movements but also their consequences on the users' performances. The following aspects have been demonstrated to affect the time for the task and the accuracy of the users' gestures: different layouts (i.e. bouton sizes) [1,9], characteristics of the devices (i.e. screen sizes) [1,11], interaction techniques (pen or finger) [11] as well as configuration of use (i.e. device on a desk, handheld or on the user's lap) [11,15].

In regard to the comfort of use, Shin and Zhu (2011) have demonstrated that using a touchscreen device on vertical position requires greater muscle activity of upper limbs compared to the use of traditional input devices such as a physical keyboard or a mouse [14]. Using a tablet on vertical or tilted position requires greater wrist extension to avoid accidental touches on the screen [18]. Consequently, there is a greater risk of discomfort or musculoskeletal injuries after a prolonged use of tactile interaction on this configuration.

Summary

The analysis of the state of the art on movement analysis of tactile interaction incites us to state that the difference of movements between older aged and younger users of touchscreen devices should yet be investigated in order to bring to help to elucidate the reasons of their different performances according to the situations of use of tactile devices

The studies reviewed reported a great mobilization of the users' wrist for executing interaction tasks on touchscreen [6,18]. In our study, the wrist articulation is determined as an index for postures and positions of the users' upper limbs. A challenge is to record postures and movements of the wrist without disturbing the movements of the users during interaction. For that, a motion capture system allows estimating articular angles of the users' wrist from the positions of anatomical markers in relation to the position of the tactile device. The evaluation of the articular angles should enable us to compare different groups of user and to identify constraining postures, presenting a risk of discomfort for the users.

In order to avoid discomfort for the user, in the present study we have chosen to place the touchscreen device horizontally on a desk. This configuration of study would allow us, in this first evaluation, to assess the movements of the wrist of older and younger users. Later, the results of the present study could be compared to other situations of use of touchscreen devices.

METHODS

In view of this analysis of the state of the art, we have implemented an experiment to register the movements of the users' wrists during interaction on touchscreen. At the same time, the users' performances of interaction were registered by the interactive system. The aim of the present study is to compare and try to understand the differences in performances between two groups of participants, older and younger adults.

Participants

Thirty participants have been recruited for this experiment: fifteen older adults, aged 65 to 84 years old (mean= 73), and fifteen younger adults, aged 18 to 45 years old (mean= 30).

During practice trials, we have observed that participants did not present any deficiency or difficulty that could hinder interaction during the experiment. Sensorial, cognitive and motor skills have been assessed through questionnaires and self-reporting, confirming our observation. All the participants had experience of use of computers and they were familiar to devices equipped with touchscreen. They were right handed and they have used their index fingers to execute the gestures of interaction.

During the experiment, participants were seated and the touchscreen device, a 10 inches screen tablet, was horizontally placed on the desk in front of them. The top of the device was at 30 cm from the edge of the desk.

Equipment

The tablet used for this experiment was a Samsung Galaxy Note 10.1 (dimensions 180x262mm, resolution 1280x800).

The motion capture system (Qualisys AB, Gothenburg, Sweden) was composed of six infrared cameras. This optoelectronic system records the position of the reflexive markers placed on the participants' bodies and on the tablet with a double-faced adhesive tape.

The six infrared cameras were disposed around de desk, their spots were approximately 3 meters height, and oriented towards the subject. The cameras registered the markers positions in three-dimensional space (X, Y, Z) are registered in a frequency of 200 Hz. Figure 1 presents an overview of the equipment used for this study.

Figure 1 Overview of the laboratory and the equipment for the study.

The anatomical markers were placed on participants' head, trunk and upper limbs according to the recommendations of International Society of Biomechanics [17]. Supplementary markers were placed on arms and forearms so the positions of the anatomical markers could be recalculated in case of obstruction of the view or defect on signal recording. Figure 2 illustrates the 3D reconstruction of the user's posture according to the markers positions.

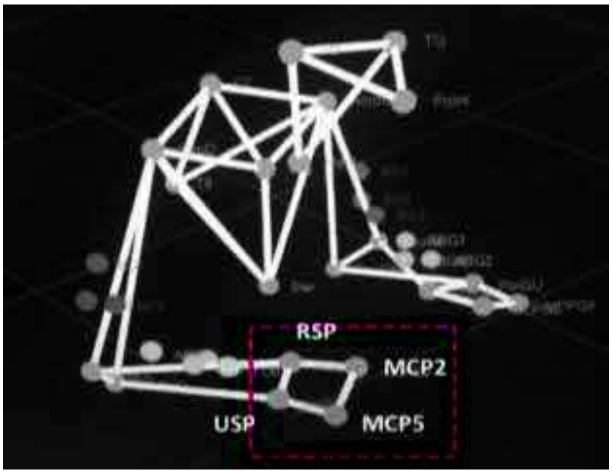

Figure 2. Illustration of the reconstruction of the posture of the user in 3D

For the analysis of the movements of the users' wrist, we have focused our study on the positions of the four anatomical markers placed on their hands: *metacarpi 2* (MCP2), *metacarpi 5* (MCP5), *radial styloid processus* (RSP) and *ulnar styloid processus* (RSP), as highlighted in Figure 3.

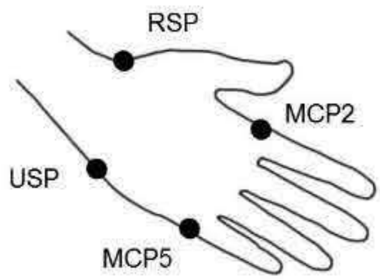

Figure 3. Illustration of the anatomical markers used for the analysis of the postures of the wrist

Task

In order to facilitate the recruitment of older aged participants, we have developed an interactive system presenting a tactile puzzle game. This approach have already been used in our previous study which allowed us to verify the ease-of-use of drag-and-drop as gesture of interaction for older aged users with different user profiles [10]. When the user touches a piece of the puzzle game with his or her finger on the screen, the selected puzzle piece is displayed on the top of the others and it can be dragged. When the user drops the piece, the system verifies if it is covering at least 95% of its corresponding target. If this accuracy requirement has been met, there is a visual feedback for the user (the piece flashes) and the piece remains fixed.

If the user is able to reach every target moving each puzzle piece with only one drag-and-drop gesture, there is no errors. The task is over when all the puzzle pieces have been correctly placed, recomposing a picture.

When the user drops a puzzle piece that does not matches the accuracy requirement for its corresponding target, the interactive system counts one accuracy error. The dropped piece remains on its last position and the user should try to drag it into its corresponding target again. Therefore, in the present study, the number of errors represent the number of supplementary gestures of the user for positioning the puzzle pieces into their corresponding targets.

Figure 4 presents two screenshots of the interactive system. The puzzle pieces are displayed on the bottom of the screen, on random positions, and they should be dragged into their corresponding targets. The grid of targets is displayed on the top of the screen, presenting a watermark of the picture to be recomposed.

Figure 4 Screenshot of the interactive system displaying two version of the game. On the left, a game with nine puzzle pieces. On the right, a game with sixteen puzzle pieces.

The parameters of the interactive system have been set to display nine large puzzle pieces (46x35 mm) and sixteen smaller puzzle pieces (35x27mm). The mean travelling distance is 110mm per target for both game settings.

Participants were instructed to execute the gestures with accuracy. At the end of each game, the experimenter set the device to present a new task. The order of the tasks has been counterbalanced. Three iterations of the task have been executed. A 15 minutes' break has been respected between iterations.

Data analysis

At total, 2250 gestures of interaction have been analyzed (30 participants x 3 iterations x 25 targets). Data from interaction registered by the interactive system (touch coordinates and timestamp) have been synchronized to the movement data.

For the analysis of the postures of the wrist, the articular angles have been estimated from the coordinates of markers MCP2, MCP5, RSP and USP in relation to the position of the device. Articular angles vary from the neutral position (α=0°) to positive or negative deviations. Extension angles are positive and flexion angles are negative.

For each participant and each task, we have calculated median angles for minimal, mean, maximal deviation angles and the amplitude of movements. Then, to estimate motor effort and discomfort of wrist positions, we have calculated the time spent on postures considered neutral (-5° to 5°) or non-neutral. Finally, we have calculated the percentage of the total time of the task to each position of the wrist.

For the analysis of the users' performances, we have calculated median time for positioning a target and median number of errors per target to each series of data registered by the interactive system.

For investigating the relationship between the characteristics of the user's movements and the user's performances, we applied the Spearman's correlation test and we report the coefficient of correlation as a result.

RESULTS

Global posture of the users' wrists

We have observed a predominance of radial deviation and extension of the users' wrist and a great amplitude of radial-ulnar and flexion-extension movements. Globally, the posture of the wrist was radial deviated 93% of the time and extended 68% of the time of the interaction task. An overview of the observed angles for the two groups of participants is presented in Table 3 for radial-ulnar deviation and Table 4 for flexion-extension angles. Differences in median values for minimal, mean, maximal angles and amplitudes between groups are significant for both radial-ulnar and flexion-extension angles (p-values < 0.05).

Groupe	Minimal	Mean	Maximal	Amplitude
Adults	0.4	16.8	35.5	33.2
Older adults	-7.5	28.6	49.2	55.8

Table 3. Radial deviation angles and amplitudes (median values)

Groupe	Minimal	Mean	Maximal	Amplitude
Adults	-4.7	3.9	18.6	22.9
Older adults	-6.0	7.5	32.5	37.2

Table 4. Extension angles and amplitudes (median values)

Characteristics of movements of the wrist during interaction

In order to provide a deeper analysis of the differences of movements between the two groups, we have calculated the percentage of the time of the task the wrist spent on different postures. We report this result by angular intervals of 5 degrees, from 45° negative to 45° positive. Deviations close to 0° are considered neutrals (-5 to 5°) and deviations greater than 30° can be considered extremes or presenting a risk for discomfort for the users [18].

For the group of adults, most of the time (55%) the wrist assumed a radial deviated posture measured from 5 to 25 degrees. Movements close to a neutral deviation represented 30% of the time of the task for this group of participants. The time spent on ulnar deviation corresponded to 12%. Radial deviation exceeded 30° during 11% of the time of the task.

For the group of older adults, most of the time (52%) the wrist assumed a radial deviated posture measured from 20 to 35 degrees. Movements close to a neutral deviation represented 13% of the time of the task for this group of participants. The time spent on ulnar deviation corresponded to 7%. Radial deviation exceeded 30° during 37% of the time.

Figure 5 and Figure 6 describe the percentage of the time the users' wrist spent on radial or ulnar deviation and the registered angles, for adults and older adults, respectively.

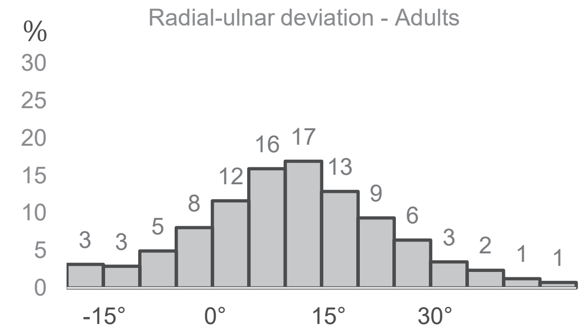

Figure 5. Percentage of the time the users' wrist spent on radial (positive) or ulnar (negative) deviation during interaction with finger on tablet – Adults

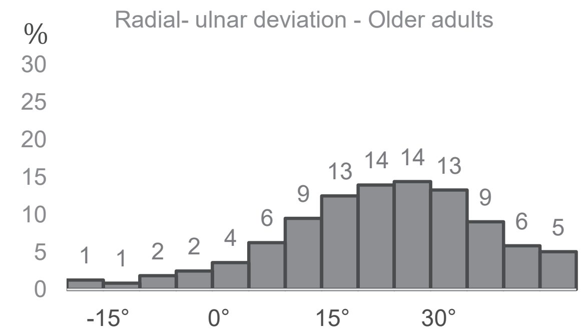

Figure 6. Percentage of the time the users' wrist spent on radial (positive) or ulnar (negative) deviation during interaction with finger on tablet – Older adults

Concerning the flexion-extension angles, results for the group of adults show that their wrists spent 68% of the time on extended posture with an angle smaller than 15°. Movements close to a neutral deviation represented 38% of the time of the task for this group of participants. Adults' wrists assumed flexed postures during 22% of the time. Extension angles have exceeded 15° during 9% of the time.

For the group of older adults, their wrists spent 60% of the time on extended postures with an angle smaller than 15°. Movements close to a neutral deviation represented 24% of the time of the task for this group of participants. Older adults' wrists assumed flexed postures during 22% of the time. Extension angles have exceeded 15° during 20% of the time.

Figure 7 and Figure 8 present the percentage of the time the users' wrists assumed flexed or extended postures, for adults and older adults, respectively, and the articular angles we registered.

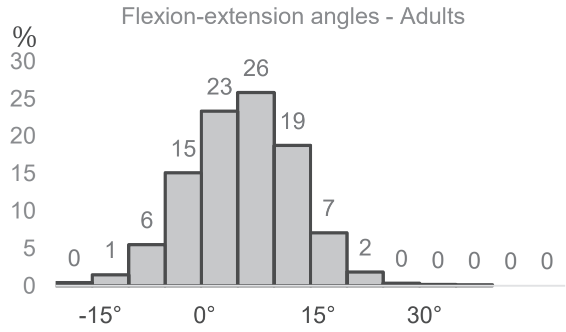

Figure 7. Percentage of the time the users' wrists spent on extension (positive) or flexion (negative) deviation during interaction with finger on tablet - Adults

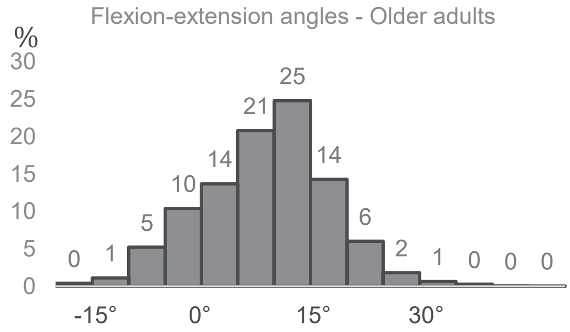

Figure 8. Percentage of the time the users' wrists spent on extension (positive) or flexion (negative) deviation during interaction with finger on tablet – Older adults

Performances

For older adults, the mean time for positioning a target was 1.7 seconds longer than for adults.

Older adults made two times more errors per target than adults did. Table 5 describes performances for the two groups of participants.

Group	Time (s)	Number of errors
Adults	2.7 (1.3)	0.2 (0.3)
Older adults	4.42 (1.5)	0.44 (0.9)

Table 5. Performances (median values and one inter-quartile interval)

For better understanding the different performances between adults and older adults, we have searched the possible relationship between results of interaction and the characteristics of the movements of the users' wrists.

For the group of adults, we have found a positive correlation between time and amplitude of movements on radial-deviation (0.4) and flexion-extension (0.6). However, the relationship between the number of errors and the amplitude of movements on radial-ulnar deviations (-0.2) and flexion-extension (-0.1) is not significant.

For the group of older adults, we have found a moderate positive correlation between time and amplitude of movements on radial-ulnar (0.3) and flexion-extension (0.4). The relationship between the number of errors and the amplitude of movements on radial-ulnar deviation (0.4) and flexion-extension (0.3) is also significant.

DISCUSSION

Our study aimed to analyze the performances of older aged users through a biomechanical analysis of the movements of their wrists. In the present section, we discuss the contribution of the movement analysis for understanding the difficulties older aged adults may find for accomplishing tactile interaction. Then, we discuss the usability of tactile interaction from an ergonomic perspective. Finally, we present the questions that raised throughout the implementation of this multidisciplinary experiment.

The relationship between users' movements and their performances during tactile interaction

In the present study, the analysis of the postures of the users' wrists during interaction with touchscreen has shown a greater amplitude of movements for older aged adults. Besides, the predominance of radial deviation and extension of the wrist was more accentuated for the older group of participants. This result describe a situation of use with an increased risk of discomfort for the users. This result could explain the longer times and bigger number of errors for the group of older aged participants. Our analysis of the relationship between the time for positioning targets and the amplitude of movements on radial-ulnar and flexion-extension of the wrist is in line with this finding.

The radial deviation angles were greater for the older aged adults than for younger participants. This result indicates that older users should adapt their movements and adopt different strategies from younger adults for accomplishing an interaction task. This result is in line with the literature describing that older aged adults prioritize the mobilization of distal articulations, such as their wrists, to the mobilization of proximal articulations, such as users' shoulders [3,16]. Additionally, the greater amplitudes of movements could also be related to the changes related to the aging in physiological and neurological systems, which can affect the postural stability of older aged adults' wrists [16].

Ergonomics of use of touchscreen devices

The characteristics of the movements of the wrist of younger participants show a smaller amplitude of movements compared to the older group. Younger adults also spent longer times close to neutral postures of radial deviation. This result represent an increased comfort of use of tactile interaction that could explain the improved performances for the younger group. This result may also be related to a finer motor skill and handiness for the younger participants.

However, the evaluation of the comfort of use of tactile interaction should be further investigated because the greater stabilization of the younger adults' wrists could have been compensated by greater mobilization of other upper limbs' articulations, such as the elbows or the shoulder, or yet by movements of the trunk [7]. Therefore, a supplementary analysis is necessary to evaluate the ergonomics of use of touchscreen devices in horizontal position for older and younger groups of users.

From an ergonomics perspective, we should consider that improving the usability of touchscreen devices might affect not only the users' performances but also their comfort of use. Reducing the time and the number of errors for accomplishing an interaction task should help users to interact more efficiently, optimizing the execution of the gestures of interaction and thus reducing the risk of developing musculoskeletal injuries after prolonged times of use of touchscreen.

Movement analysis for understanding users' performances during interaction with touchscreen

In the present study, the biomechanical analysis of the movements of the users allowed us to collect data supplementary to those recorded by the interactive system for interpreting the differences in performances between older and younger adults. The results we obtained from the methods we employed present nevertheless some limitations.

In regards to the characteristics of the participants, it is difficult to gather a homogeneous group of older aged adults, particularly concerning the factors affecting the evaluation of their interaction with technologies. The heterogeneity of the group of participants recruited for the present study could partially explain the increased variability of postures of the wrist that have been observed as well as the greater variability of performances of this group of users compared to the younger adults. However, the differences in postures and performances between the two groups of participants remain significant. We argue that the analysis of the movements of users with different motor skills or disabilities could reveal new insights for the design of interactive technologies better adapted to the needs of particular groups of users.

The equipment we used to record movement data has been chosen because it is non-invasive and it does not hinder the execution of the users' movements during interaction with touchscreen. However, the motion capture system is voluminous, so participants should move to the university's laboratory where the equipment has been installed. This restriction was a constraint for the recruitment and the participation of older aged adults. Another constraint was the placement of the anatomical markers, on the users' skin or tight fitting clothes. This sometimes presented a barrier to the acceptability of the experimental procedure.

The configuration of the experiment in our study was set to enable a comfortable situation for the participants during the experiment as well as to facilitate the participation of older aged adults. In the present study, the analysis of the postures of the users' wrists allowed us to compare the movements between the two groups of participants. However, the perception of the comfort is an individual measure and it relies on the motor abilities of each person. In order to better estimate the user's comfort or discomfort of use of touchscreen, it is important to take into consideration their individual characteristics. For example, future work should measure maximal articular deviation angles and maximal amplitude of movements for each participant in order to compare to the results obtained during the experiment. Additionally, physiological measures and comfort self-reporting evaluation should be consider for longer lasting experiments and for the study of the comfort of prolonged time of use of touchscreen.

Future work

For future work, movements of the users' elbows and shoulders should be analyzed in order to identify compensatory movements from these articulations. Compensatory movements could be the result of different users' strategies for executing gestures of interaction or yet the result of some difficulty of movements or disabilities of the users' upper limbs.

Further evaluation should also help to identify postures increasing the risk of discomfort or musculoskeletal injuries for the users. It would be important to evaluate the use of touchscreen devices with different interaction techniques (e.g. a pen), devices (e.g. smartphone, tabletop) or other configurations (e.g. handheld devices or on vertical positions) in order to provide ergonomics recommendations for designers and users.

CONCLUSION

We have studied the differences in performances between older and younger adults through a biomechanical analysis of their movements. The analysis of the postures of the users' wrists has shown a greater amplitude of movements for older adults, with more accentuated radial deviation and extension angles for this group of users compared to younger adults. We found a relationship between this characteristic of movements and the longer times and increased number of errors for the older participants. This result indicates a discomfort for executing the gestures of interaction on touchscreen that could explain the differences in performances between older and younger adults.

In the present study, the wrist articulation is an index of the arrangements of the postures and positions of the users' upper limbs. Further evaluation would help to elucidate the different strategies employed by older users to accomplish interaction on touchscreen, according to the different situations of use of these devices. The biomechanical analysis of the users' movements would allow the identification of the situations presenting a risk for the users of developing muscle-skeletal disorders and the elaboration of recommendations for improving the comfort of use of touchscreen.

The association of the analysis of the users' movements to the study of the usability of interactive technologies provide additional information about the interaction for the interpretation of the results. The main contribution of the present study is the identification of differences in the characteristics of movements between older and younger adults during interaction with touchscreen, such as the amplitudes of the articular angles of their wrists. This analysis allows designers to understand interaction from an ergonomic point of view and offers the possibility to design solutions that are better suited to the users' needs.

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